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SEMINAR ON CONTRAST TWO-DIMENSIONAL ECHOCARDIOGRAPHY: APPLICATIONS AND NEW DEVELOPMENTS. PART V*

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*Guest Editors*

# Retrograde Coronary Venous Contrast Echocardiography: Assessment of Shunting and Delineation of Regional Myocardium in the Normal and Ischemic Canine Heart

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**Coronary venous injections of sonicated Renografin-76 were performed in seven closed chest dogs during two-dimensional echocardiography to study the ability of this new technique to opacify regional myocardium before and after occlusion of the left anterior descending coronary artery. The balloon of a 4F double lumen catheter was inflated in the great cardiac vein for each contrast injection to prevent backflow through the coronary sinus into the right atrium. Retrograde injections before coronary artery occlusion generally resulted in patchy myocardial contrast uptake. Injections after coronary occlusion always resulted in confluent and transmural myocardial opacification which occupied 42.8 ± 8.6% (range 26 to 54) (mean ± standard deviation) of the myocardial circumference. Retrograde opacification always extended into adjacent myocardium beyond the ischemic zone, which was assessed in echocardiograms with antegrade contrast injections into the left main coronary artery and which measured 30 ± 6.3% of the ventricular circumference.**

**Shunting from the coronary venous system to cardiac chambers was evaluated in a parasternal four chamber view and was graded on a scale of 0 to 4+. Contrast appearance was equally intense in the right atrium and right ventricle (3.5 ± 0.6+, range 2+ to 4+), less intense in the left ventricular cavity (1.5 ± 0.6+, range 1+ to 3+) and absent in the left atrium. Postmortem anatomic validation with retrograde great cardiac vein injections of indocyanine green corroborated the in vivo contrast appearance in chambers.**

**Retrograde coronary venous contrast echocardiography appears capable of providing in vivo information about the extent and location of myocardial zones that can be reached by retrograde infusions of therapeutic agents and about the ability of these agents to reach ischemic myocardium. In addition, this new method allows for in vivo evaluation of shunts between coronary veins and cardiac chambers, which may influence the efficacy of retrograde interventions.**

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Increasing attention is being paid to the coronary venous system as a promising alternate route for delivery of a variety of therapeutic interventions to the myocardium. Synchronized retroperfusion with arterial blood (1), as well as intermittent occlusion of the coronary sinus (2,3), appears capable of decreasing infarct size in the setting of experimental coronary occlusion. Initial experiences with retrograde application of streptokinase (4), antiarrhythmic agents (5) and hypothermic cardioplegic solutions (6) also appear promising and may have advantages over antegrade application by means of the arterial pathway. Nevertheless, compared with our knowledge about the coronary artery system, the anatomy and physiology of the cardiac veins remain less well defined. Only little is known about the location and extent to which a specific vein subserves a myocardial zone and whether it can, therefore, be used to apply a selective retrograde intervention to this region.

It is also necessary to elucidate the variability and significance of coronary veno-venous shunts, as well as of direct connections between the coronary veins and cardiac chambers. The existence of such interconnections has been well documented, and it appears likely that any retrograde injection will result in some direct leakage into cardiac chambers, thereby diminishing the fraction of injectate that might reach the myocardial microcirculation. Furthermore, the extent to which retrograde coronary venous infusions of arterial blood or drugs actually penetrate into regions of ischemic myocardium is not well established.

Since the ability of contrast echocardiography to map coronary arterial perfusion beds and delineate myocardial perfusion defects after experimental coronary artery occlusions has recently been demonstrated (7,8), we utilized this method for in vivo study of the coronary venous system in a canine model. The purpose of our work was to: 1) evaluate the ability of retrograde coronary venous contrast injections to penetrate regions of myocardium during the control state and after coronary artery occlusion; 2) study the extent and location of retrogradely induced myocardial contrast opacification in relation to alternately delineated perfusion defects; and 3) examine shunting from the coronary venous system into cardiac chambers.

## Methods

**Experimental preparation.** We studied seven dogs weighing 25.8 ± 4.2 kg (range 21 to 33). The dogs were premedicated with morphine sulfate (1.5 mg/kg intramuscularly) and anesthetized with sodium pentobarbital (30 mg/kg intravenously). Ventilation was performed with room air using a Harvard respirator and a cuffed endotracheal tube. Under fluoroscopic control, a 4F double lumen balloon catheter was placed in the coronary sinus by way of the left jugular vein and advanced to the great cardiac vein. A 9F angiographic catheter was inserted into the left carotid artery and positioned in the aortic root for monitoring of arterial pressure. This catheter was also subsequently used for contrast injections into the left main coronary artery and to pass a 2F balloon catheter into the left anterior descending coronary artery for the purpose of intracoronary balloon occlusion.

**Echocardiographic imaging.** Two-dimensional echocardiographic studies were performed using a 90° mechanical sector scanner equipped with a 3 MHz transducer. The studies were performed as previously described (9) with the dog on its right side and the transducer placed on the right chest wall, pointing upward. Gain settings were individually adjusted at the beginning of each study and not changed throughout its course. Two-dimensional echocardiographic images of the left ventricle were thus obtained in long-axis as well as a short-axis cross-sectional plane at the low papillary muscle level, and recorded on ½ inch (1.27 cm) videotape for subsequent analysis.

**Contrast studies.** Renografin-76, which was sonicated as previously described (10), served as the contrast agent for both fluoroscopic and two-dimensional echocardiographic studies; microbubbles produced by this method in this particular agent have been shown to measure 10 ± 4 μ. All echo contrast injections were performed using simultaneous fluoroscopic verification. Two injection sites were used in all studies:

1) Antegrade injections of 2 ml of sonicated echo contrast material were performed selectively into the left main coronary artery through the 9F angiographic catheter. These injections were carried out during the control state and after balloon occlusion of the left anterior descending coronary artery. Simultaneous fluoroscopy was used to ascertain that both the left anterior descending and circumflex coronary branches were injected simultaneously. This approach was felt to be necessary to avoid accidental subselective injections, which can occur in the dog model because of the shortness of the left main coronary artery.

2) Retrograde injections were performed into the great cardiac vein through the 4F double lumen balloon catheter. For this purpose, we inflated the balloon with 0.5 to 1 ml of Renografin-76 to achieve occlusion of the coronary vein, and then injected 5 ml of echo contrast material through the center lumen of the catheter over a period of approximately 5 seconds. The balloon was deflated 10 seconds after termination of the injection. Simultaneous fluoroscopy was utilized to assure that the balloon was firmly wedged and that there was no leakage of contrast material to the coronary sinus. All injections were performed by the same investigator, using approximately the same injection force.

**Experimental protocol.** After catheter insertion and stabilization of the dog's hemodynamic state, baseline echocardiographic images were recorded. Two ml of echo contrast agent were then injected into the left main coronary artery to document that no perfusion defect was present during the control state. To study the ability of retrograde contrast injections to opacify myocardium in the absence of

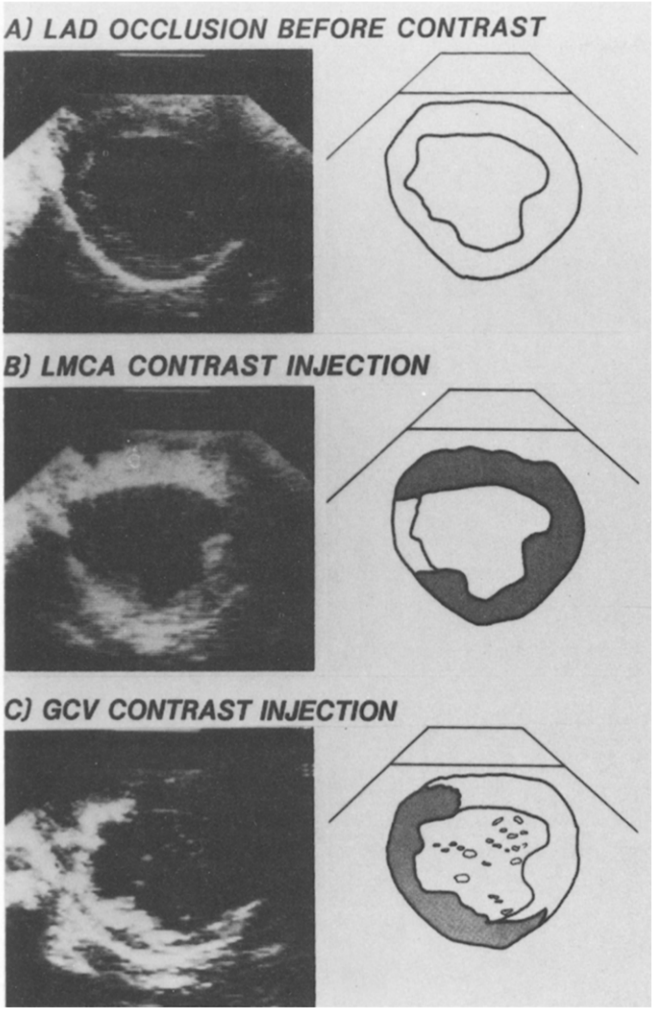


**Figure 1.** Antegrade and retrograde echocardiographic contrast studies after occlusion of the left anterior descending (LAD) coronary artery. **A**, Baseline image before contrast injection. **B**, Injection into the left main coronary artery (LMCA) results in myocardial opacification with a filling defect in the underperfused region (approximately 8 to 10 o'clock). The diminished contrast intensity adjacent to the posteromedial papillary muscle (approximately 2 to 4 o'clock) is due to echo dropout, which is most likely caused by lung interference. **C**, Retrograde great cardiac vein (GCV) contrast injection results in transmural myocardial opacification of the underperfused zone as well as of adjacent myocardium (approximately 5 to 11 o'clock). Contrast can also be noted within the left ventricular cavity.

coronary artery occlusion, we inflated the balloon within the great cardiac vein and hand-injected 5 ml of echo contrast material over a period of 5 seconds. The balloon was deflated 10 seconds after injection.

The left anterior descending coronary artery was then occluded below the first septal branch by threading a 2F balloon catheter through the 9F angiographic catheter and inflating the balloon with 0.5 to 1 ml of Renografin. Ten to 15 minutes after coronary occlusion, we repeated the left main coronary artery injections of the echo contrast agent

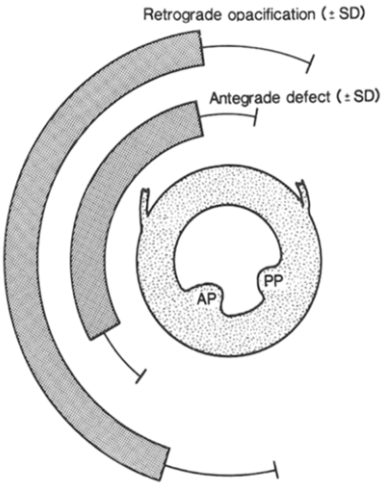


**Figure 2.** Extent and relation of antegrade perfusion defect and retrograde myocardial opacification in seven dogs. AP = anterior papillary muscle; PP = posterior papillary muscle.

to delineate the underperfused zone. Contrast injections into the great cardiac vein were then performed during left anterior descending coronary artery occlusion in the manner described for the control state.

**Image analysis.** Contrast injections into the left main coronary artery and the great cardiac vein were analyzed from end-diastolic freeze frame images of the left ventricular cross section. A transparent plastic foil was placed on the video screen and endocardial and epicardial outlines as well as the borders between zones with and without contrast uptake were traced using a grease pencil. The chosen edge delineation was reviewed during slow and fast dynamic replay of the videotape. The obtained drawings were then retraced on a digitizing tablet. The center of gravity of the epicardial outline was determined by a computer, and lines were drawn between it and the borders of contrast uptake. The resulting angle, which reflected the circumferential extent of the myocardial zone, was measured and expressed as a percent of left ventricular circumference of the echographic cross section.

*To compare the extents of myocardial opacification* obtained with the first and second retrograde injections, the mean percent error of the measurement was calculated using the formula:

$$\text{Mean \% error} = \frac{[\text{A(max)} - \text{A(mean)}] \times 100}{\text{A(mean)}},$$

where A(max) represents the larger angle and A(mean) the average of the two angle measurements.

*The magnitude of direct shunting from the coronary venous circulation to cardiac chambers* in parasternal four chamber planes was evaluated semiquantitatively by two blinded observers who graded the appearance of contrast

**Table 1.** Myocardial Delineation After Left Anterior Descending Coronary Artery Occlusion: Extent of Contrast Filling Defect With Left Main Coronary Artery Injection Versus Myocardial Opacification After Retrograde Great Cardiac Vein Injection

| Dog | Antegrade Defect | Retrograde Opacification | | |
|---|---|---|---|---|
| | | Injection 1 | Injection 2 | Mean |
| 1 | 34 | 33 | 48 | 40.5 |
| 2 | 37 | 50 | 36 | 43 |
| 3 | 21 | 54 | 51 | 52.5 |
| 4 | 36 | 48 | 50 | 49 |
| 5 | 32 | 46 | 48 | 47 |
| 6 | 26 | 41 | 42 | 41.5 |
| 7 | 24 | 26 | – | 26 |
| Mean ± SD | 30 ± 6.3 | | | 42.8 ± 8.6 |

Values represent percent of left ventricular short-axis cross-sectional circumference.

within the chamber on a scale of 0 to 4+, where 0 = no contrast, 1+ = few isolated bubbles seen in chamber, 2+ = numerous bubbles without confluescence, 3+ = numerous bubbles with areas of confluescence opacifying portions of the chamber and 4+ = contrast opacification of the whole chamber.

**Anatomic validation of shunting.** After termination of echocontrast studies, the dog was killed by intravenous injection of potassium chloride. In three dogs, the heart was excised and used for anatomic validation of the shunt studies. After opening both atria, the 4F double lumen balloon catheter was reinserted into the coronary sinus and advanced to the great cardiac vein. The balloon was then inflated so that the catheter was firmly wedged within the vessel. Indocyanine green was injected in 1 ml increments and both atria were inspected for evidence of leakage of dye. In addition, both ventricles were inspected through the atrioventricular valves. For better visualization of the endocardial surface, both ventricles were then carefully cut open with single incisions into the free walls, starting from the apexes. The atrioventricular rings were left intact. Great care was used to avoid damaging any of the visible epicardial veins. The heart was then washed with tap water, and dye injection into the great cardiac vein was repeated as described.

## Results

**Antegrade left main coronary artery injections.** During the control state, injections of echo contrast material into the left main coronary artery always resulted in two-dimensional echocardiographic opacification of the entire left ventricular short-axis cross section. After occlusion of

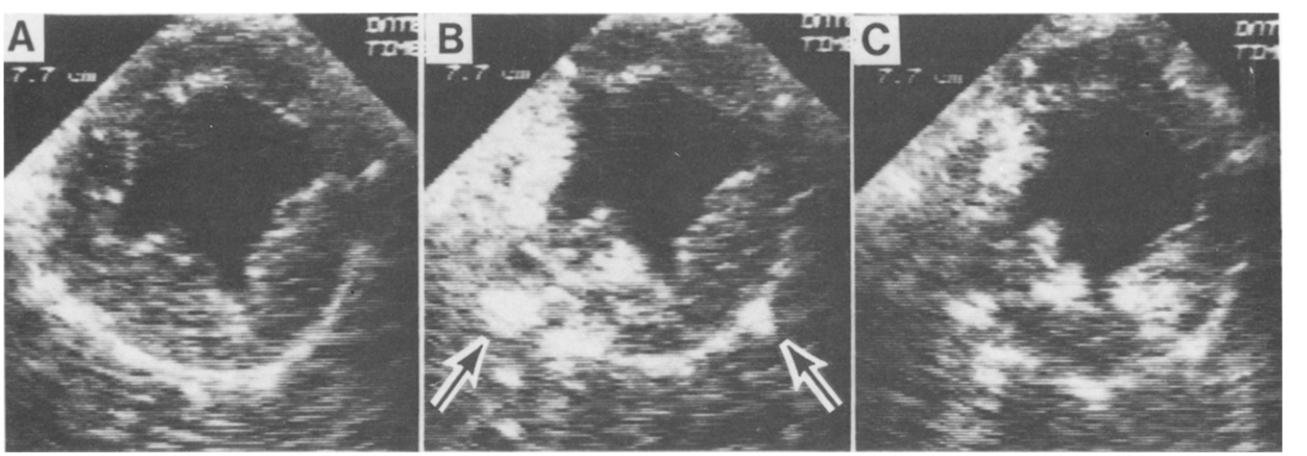


**Figure 3.** Retrograde coronary venous contrast injections without coronary artery occlusion. **A,** Baseline image. **B,** Great cardiac vein injection results in patchy myocardial opacification. The bright rounded structures **(arrows)** presumably represent epicardial coronary veins containing contrast material. **C,** Coronary sinus injection also results in patchy but more extensive myocardial opacification which now also involves the posterior papillary muscle.

the left anterior descending branch, left main coronary artery injections always resulted in a well defined contrast filling defect in the region of the anterior wall (Fig. 1 and 2), frequently also involving a portion of the ventricular septum. The defect involved 30 ± 6.3% (range 21 to 37) (mean ± standard deviation) of the left ventricular short-axis section circumference (Table 1).

**Retrograde coronary venous injections.** Before coronary artery occlusion, injections into the great cardiac vein (Fig. 3, Table 2) frequently resulted in patchy nontransmural myocardial opacification or (in two instances) in no opacification at all. After occlusion, the retrograde injections always resulted in confluent and transmural myocardial opacification (Fig. 1, Table 2).

**Extent of myocardial opacification after coronary artery occlusion.** Contrast injections into the great cardiac vein opacified not only the entire region of the filling defect that had been observed with the antegrade injection, but almost always also extended into adjacent myocardium (Fig. 1 and 2). The myocardial zone of retrograde uptake of contrast material involved 42.8 ± 8.6% (range 26 to 54) (mean ± standard deviation) of the left ventricular short-axis section circumference (Table 1). Mean injection to injection measurement error of this retrogradely delineated myocardial zone in six dogs was 7.2 ± 8.0%. In a seventh dog, the second retrograde injection could not be performed because the balloon on the coronary sinus catheter was accidentally damaged by overinflation.

**Shunting from coronary veins to cardiac chambers.** Every coronary venous injection was associated with the appearance of echo contrast in both left and right cardiac chambers. Simultaneous fluoroscopy confirmed complete balloon occlusion of the coronary vein and, thus, excluded direct coronary sinus backflow into the right atrium as a cause for this contrast appearance.

In five of the dogs, we performed coronary venous contrast injections during the control state while recording echocardiographic parasternal four chamber views. Immediately after the retrograde injection, contrast was seen in the right atrial and ventricular chambers, followed almost instantaneously by appearance within the left ventricular myocardium and cavity (Fig. 4 and 5). Myocardial opacification

**Table 2.** Type of Myocardial Opacification With Contrast Injection Into the Great Cardiac Vein

| | Injections Before LAD Occlusion | | Injections After LAD Occlusion | |
|---|---|---|---|---|
| Dog | 1 | 2 | 1 | 2 |
| 1 | C | O | C | C |
| 2 | P | P | C | C |
| 3 | O | C | C | C |
| 4 | P | P | C | C |
| 5 | P | C | C | C |
| 6 | P | P | C | C |
| 7 | C | C | C | C |

C = confluent transmural opacification; LAD = left anterior descending coronary artery; O = no myocardial opacification; P = patchy nontransmural opacification.

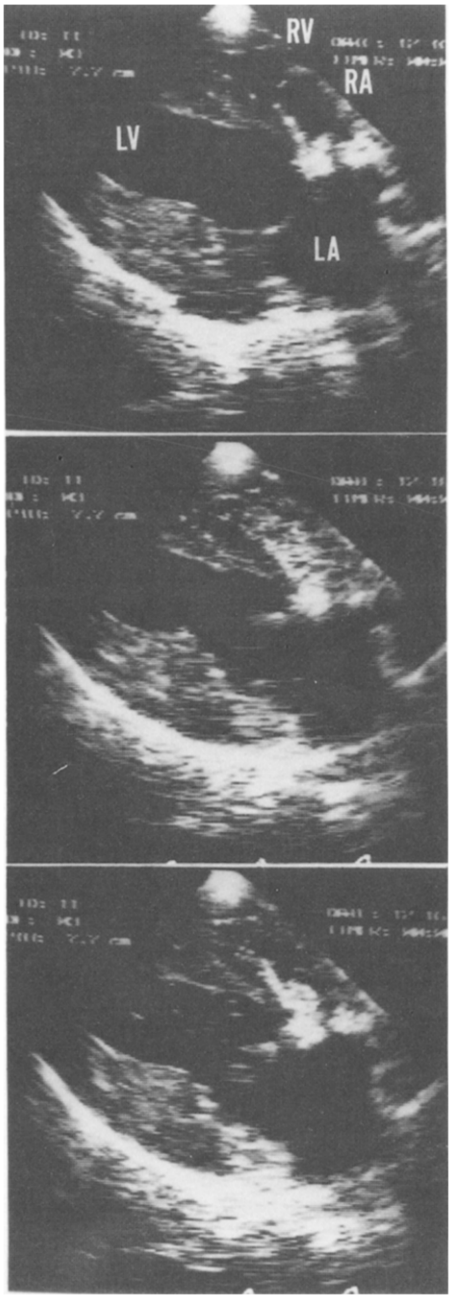


**Figure 4. Top,** Parasternal four chamber view during control state. **Middle,** Injection into the great cardiac vein results in the appearance of bright contrast in the right atrium (RA) and right ventricle (RV). **Bottom,** Several cardiac cycles later, the contrast in the right side of the heart has disappeared; a small amount of contrast material is still seen within the left ventricular (LV) cavity, but not within the left atrium (LA). Although opacification of left ventricular myocardium had been obvious on short-axis views, no such effect can be seen in the long-axis view because the echocardiographic plane fails to transsect the area of myocardial contrast uptake.

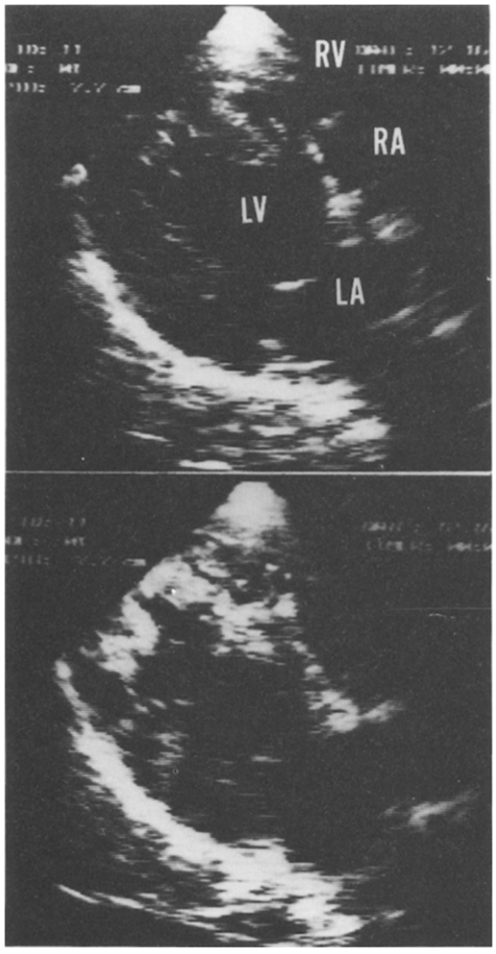


**Figure 5.** Parasternal four chamber view. **Top,** Control state. **Bottom,** In this particular dog, contrast injection results in extensive left ventricular (LV) myocardial opacification involving the ventricular septum, apex and a portion of the posterior wall. Abbreviations as in Figure 4.

was frequently less extensive than in the short-axis views and was occasionally absent, presumably because the imaging plane often failed to transsect the zone of contrast uptake. In four dogs, we were able to visualize at least one of the sources of left ventricular chamber contrast; a contrast jet was observed to originate near the base of the anterior papillary muscle and quickly dispersed within the chamber (Fig. 6).

**Semiquantitative evaluation of coronary vein to cardiac chamber shunting (Table 3).** The appearance of contrast was most intense in the right atrium and right ventricle and was graded as 3.5 ± 0.6+ (range 2 to 4+) for individual injections. Both of these chambers were always graded identically. Contrast within the left ventricle was less intense and was scored as 1.5 ± 0.6+ (range 1 to

**Figure 6.** Time sequence of short-axis images at the low papillary muscle level. **A,** Control state. **B through F,** Contrast injection into the great cardiac vein. In addition to myocardial opacification (approximately 7 to 12 o'clock), there is passage of contrast material into the left ventricular cavity near the base of the anterior papillary muscle **(arrow in B),** resulting in a contrast jet **(C through E)** which finally breaks up and disperses **(F).**

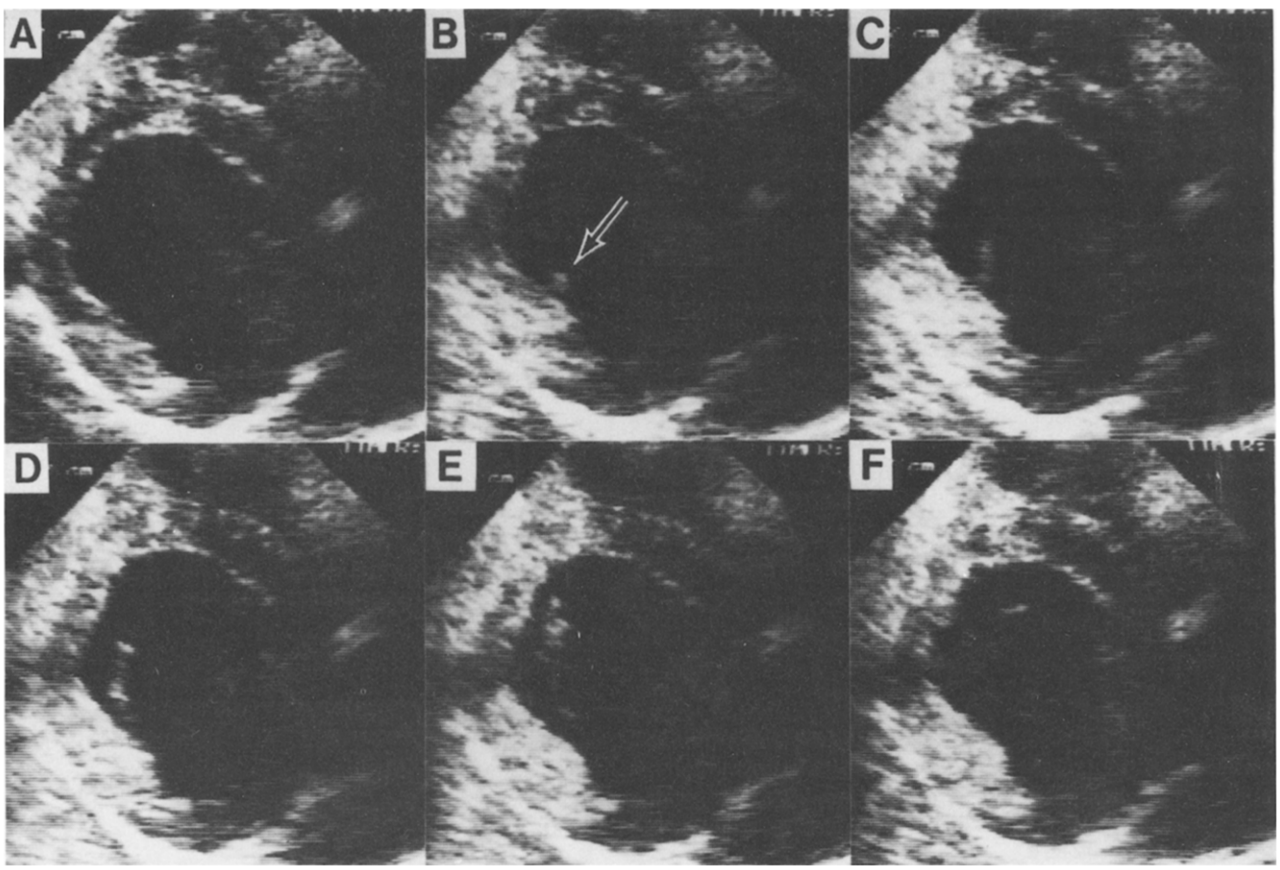

**Table 3.** Intracavitary Contrast Appearance After Great Cardiac Vein Injections

| Dog | LA | LV | RA | RV |
|---|---|---|---|---|
| 1 | 0 | 1 | 3.5 | 3.5 |
| 2 | 0 | 2.5 | 3.5 | 3.5 |
| 3 | 0 | 1 | 2.5 | 2.5 |
| 4 | 0 | 1.5 | 4 | 4 |
| 5 | 0 | 1.5 | 4 | 4 |
| Mean ± SD | 0 | 1.5 ± 0.6 | 3.5 ± 0.6 | 3.5 ± 0.6 |

Averages for two injections are given. LA = left atrium; LV = left ventricle; RA = right atrium; RV = right ventricle; SD = standard deviation.

3+). In no instance could we detect the appearance of contrast in the left atrial cavity.

The interobserver and interinjection agreement for the scoring of intracavitary contrast intensity is illustrated in Tables 4 and 5. Discrepancies never exceeded one grading step and predominantly occurred between grades 2+ and 3+.

**Anatomic validation.** Postmortem injections of indocyanine green into the great cardiac vein resulted in the appearance of dye in the orifices of venous branches draining into the coronary sinus near its atrial junction, as well as in several places on the endocardial surface of the right atrial free wall. Although we could also observe some dye appearing on the inner surface of the left atrial free wall, it seemed to occur to a lesser degree and only after a larger volume of injectate. In the right ventricular cavity, dye appeared between trabeculations near the apical region, as well as from multiple small foramina that were located just below the tricuspid valve (Fig. 7, top). In the left ventricular cavity, leakage of dye was most prominent from a single small orifice located near the base of the anterior papillary muscle (Fig. 7, bottom).

## Discussion

**Retrograde myocardial contrast opacifiacition.** Echocardiographic myocardial opacification by means of retrograde coronary venous injections of contrast agent has not been previously described. Using our new methodology, we were able to demonstrate this phenomenon in each of our laboratory animals. After occlusion of the left anterior descending coronary artery, transmural and confluent opacification of a myocardial zone could be achieved with every single retrograde coronary venous injection, however, before the occlusion we frequently only obtained patchy nontransmural opacification, and with two injections no opacification was seen. The latter differences may be due to the difficulty of retrograde injection against full antegrade blood flow in the presence of normal coronary arteries. Our results are in support of previous studies that noted preferential flow to the ischemic area as compared with the normally perfused myocardium with retrograde injections of krypton-85 (11) or when delivering radioactive microspheres by means of synchronized retroperfusion (12). After coronary occlusion, retrograde contrast injections opacified not only the underperfused zone, but also the adjacent myocardium. The zone of myocardial contrast uptake never occupied more than roughly half of the left ventricular circumference as seen on two-dimensional echocardiographic short-axis cross sections at the low papillary muscle level, and was always located in the region of the anterior wall and the adjacent portions of the ventricular septum and lateral wall (Fig. 1 and 2). Great cardiac vein injections never resulted in opacification of the posterior or inferior walls or of the inferior part of the septum.

Thus, the outlined area probably represents mostly the anatomic distribution of the anterior interventricular veins which accompany the left anterior descending coronary artery, and perhaps that of other distal branches of the great cardiac vein (13–16). The location of the intravenous occluding balloon did not permit access to the posterior left ventricular vein, which usually runs along the obtuse margin of the heart. Another of the larger branches, the middle cardiac vein, which is located in the posterior interventricular sulcus, usually drains into the very proximal coronary sinus. To be accessible for retrograde injections, this vessel would, therefore, probably require selective cannulation because its orifice would usually be occluded by a balloon catheter positioned near the beginning of the coronary sinus. The same is most likely true for the small cardiac vein, which runs along the atrioventricular groove between the right atrium and ventricle and also drains into the proximal coronary sinus.

Thus, our preliminary observations suggest that retro-

**Table 4.** Interobserver Agreement for Contrast Intensity in Individual Cardiac Chambers

| | Observer 1 | | | | |
|---|---|---|---|---|---|
| | 0 | 1+ | 2+ | 3+ | 4+ |
| Observer 2 | | | | | |
| 0 | 10 | – | – | – | – |
| 1+ | – | 6 | – | – | – |
| 2+ | – | – | 3 | 3 | – |
| 3+ | – | – | 1 | 5 | 1 |
| 4+ | – | – | – | – | 11 |

**Table 5.** Interinjection Agreement for Contrast Intensity in Individual Cardiac Chambers

| | Injection 1 | | | | |
|---|---|---|---|---|---|
| | 0 | 1+ | 2+ | 3+ | 4+ |
| Injection 2 | | | | | |
| 0 | 5 | – | – | – | – |
| 1+ | – | 2 | 2 | – | – |
| 2+ | – | – | – | 1 | – |
| 3+ | – | – | 2 | – | 2 |
| 4+ | – | – | – | 2 | 4 |

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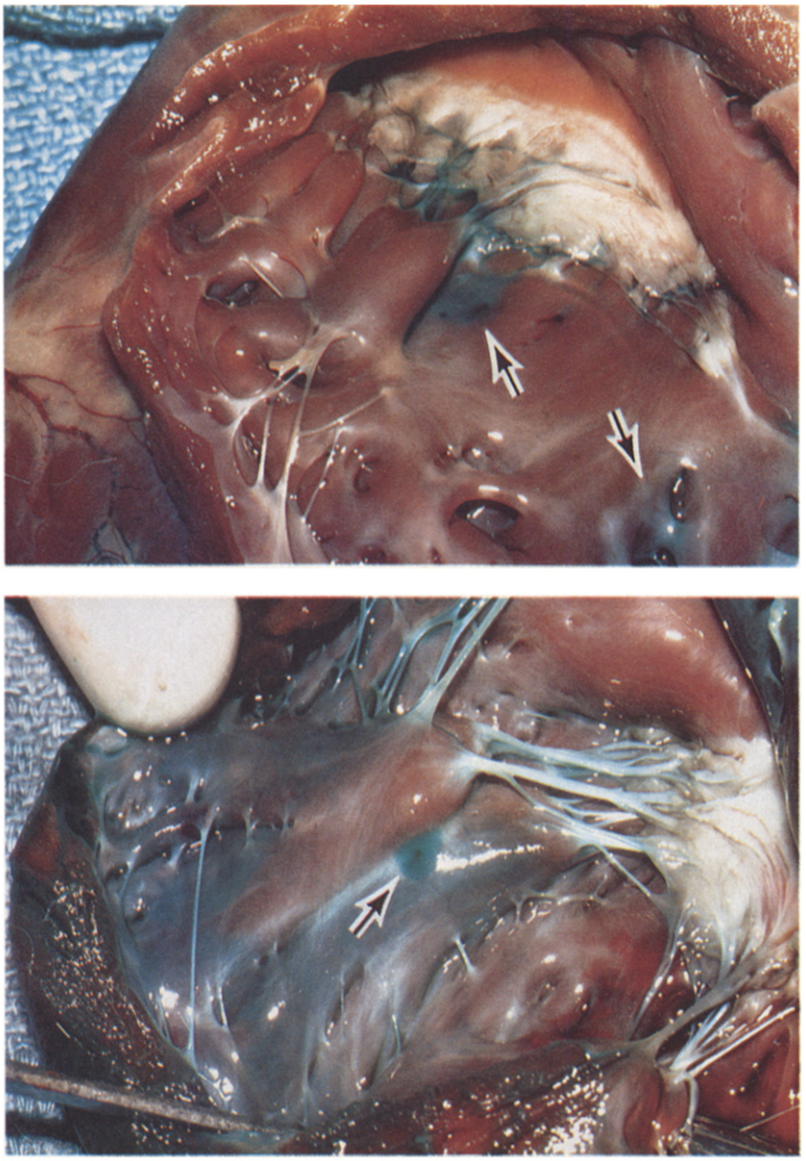

**Figure 7.** Postmortem specimens after retrograde great cardiac vein injection of indocyanine green. **Top,** Right ventricle. Injection results in appearance of dye at the endocardial surface of the right ventricle from small foramina below the tricuspid valve **(top arrow),** as well as between trabeculations **(bottom right arrow). Bottom,** Left ventricle (same dog as in Fig. 6). Injection results in appearance of dye from an orifice at the base of the papillary muscle **(arrow).**

grade penetration of contrast material into the myocardium appears to be affected by at least two factors: anatomic distribution of the vessels distal to the catheter tip and magnitude of arterial blood flow to the myocardial zone. These factors may also account for the greater extent of retrograde opacification as compared with the antegrade filling defect, although the exact mechanisms are currently not well understood.

Additional studies are needed to further investigate these hypotheses. Injections into the proximal coronary sinus should be compared with injections into the great cardiac vein and subselectively cannulated smaller branches. Preliminary evidence suggests that the extent of myocardial opacification achieved from the coronary sinus is greater (Fig. 3) than from the great cardiac vein, although still not involving the entire left ventricular circumference. Further experiments in the presence of circumflex coronary artery occlusion should help to evaluate the degree of affinity of retrograde injections for ischemic myocardium, as well as to clarify the possible role of coronary veno-venous shunts. Computer videodensitometry (17) may be helpful to assess differences in contrast intensity within the opacified region as well as their time course, and may thus offer quantitative information on perfusion beyond mere delineation.

**Shunting to cardiac chambers.** Direct connections between the coronary venous system and cardiac chambers were described by Thebesius in 1716 (18). With the application of newer interventions employing the coronary venous system as an alternate pathway to reach jeopardized myocardium (1–6), these thebesian connections might have a new and previously not appreciated significance because they could cause direct leakage of a currently unknown fraction of the injectate into the cardiac chambers. A previous study (19), using an isolated perfused dog heart prep-

aratiom demonstrated that augmentation of coronary sinus pressure resulted in a marked increase in direct shunting into the right and to a lesser degree the left cardiac chambers. When coronary sinus pressure approached 35 to 40 mm Hg, drainage through the coronary sinus stopped completely and approximately 85% of coronary venous outflow passed directly to the right heart chambers, while the remaining 15% drained into the left heart chambers. The study did not attempt to differentiate between atrial and ventricular drainage.

Ouc findings with retrograde echo contrast injections in vivo and indocyanine green dye injections postmortem must be considered only semiquantitative, but they also suggest the presence of significant direct drainage into the right side of the heart and a lesser degree of drainage into the left side of the heart. With the methodology we used, in vivo differentiation between direct right atrial and right ventricular outflow is difficult, although such differentiation might be possible in the future using a smaller amount of injectate and frame by frame analysis. On the left side, however, it appears that most of the in vivo drainage occurs directly into the left ventricle since we were never able to observe any contrast effect within the left atrium. Computer videodensitometry within each of the cardiac chambers may offer additional insights in the relative magnitude of flow into each of the cavities.

**Limitations of study.** A major limitation of our preliminary study is that we performed injections manually without actually measuring injection pressure, although all studies were performed by the same investigator, who consciously attempted to always apply the same injection force. Further experiments are needed to carefully study the role of different injection pressures and volumes. As mentioned earlier, there is also a need to evaluate injections into the proximal coronary sinus and venous branches and to also study myocardial opacification in the setting of circumflex coronary artery occlusion. Our comparison of myocardial contrast with and without coronary artery occlusion and the evaluation of contrast appearance in cardiac chambers are only subjective and could be improved by the use of computer videodensitometric methods. Furthermore, we do not have any information on whether the coronary venous contrast injections actually resulted in penetration into the microcirculation or merely outlined the distribution of larger intramural veins. Validations with other, more established methods, such as radioactive microspheres, should help to answer some of our questions.

**Significance and potential implications.** Retrograde coronary venous contrast echocardiography could contribute to our understanding of cardiac anatomy and physiology by allowing for in vivo identification of zones of myocardium that are subserved by individual veins and by offering information about connections between veins and cardiac chambers. In addition, it may serve as an investigational tool that could aid our understanding of retroperfusion, intermittent coronary sinus occlusion as well as retrograde drug infusions by identifying regions of myocardium that can be reached by these interventions and by establishing their relation to the ischemic zone. An additional potential application could be the retrograde delivery of a myocardial echo contrast agent into ischemic regions for evaluation of myocardial blood flow by means of echo contrast "washout" analysis (17). Further studies should offer additional insights regarding applicability and usefulness of this new methodology.

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